

**RESEARCH FLIGHT MANAGEMENT SYSTEM**  
**B-757 BASELINE HARDWARE CONFIGURATION**

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# RESEARCH FLIGHT MANAGEMENT SYSTEM

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# RESEARCH FLIGHT MANAGEMENT SYSTEM

## 1.0 INTRODUCTION

### 1.1 GENERAL

The Research Flight Management System (FMS) used aboard the NASA Aircraft Research Integrated Experiments System (ARIES) B-757 aircraft is an additional and separate FMS system used for flight research. The centerpiece of the Research FMS is the Honeywell Flight Management Computer - Product Improvement Package (FMC-PIP) which is the same as the fully certified FMC used on the Boeing 757/767 and 747-400 aircraft. The Research FMC is identical to the basic aircraft dual installation but differs in software load, options, and interfaces. The current baseline ARIES Research FMS as documented here is one half of the planned dual research FMS. The NASA Transport Research Facilities Requirements Document calls for a "hardware" as well as a "software" version of the research FMS. The software version is still in development and will exist totally within the applications software of the ARIES main research flight computer, a Silicon Graphics Inc. Onyx Computer.

### 1.2 PURPOSE

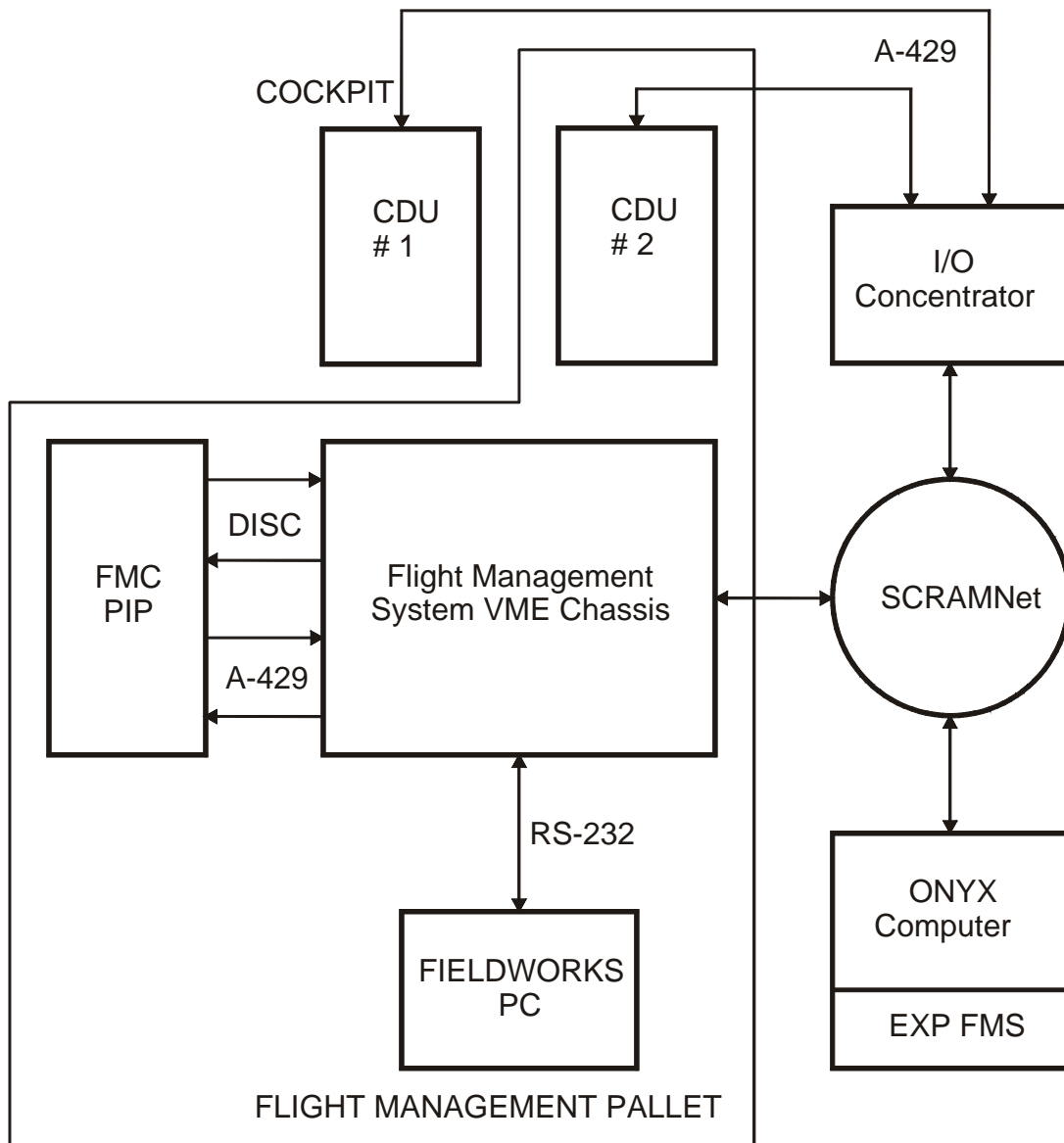
The purpose of this report is to formally document the Baseline Research FMS hardware installation for use as needed and to provide information for a revised system to support the planned ARIES Research Flight Deck (RFD) development. This document covers the baseline hardware version of the Research FMS with the Honeywell FMC-PIP being the central hardware piece of the system. Once fully implemented, the Research FMS can be switched between the hardware and software versions according to the flight research requirements. This document is intended to supplement existing documentation in the form of Aircraft Work Orders, Experimental System Work Requests, Experimental System drawings and wiring diagrams used to implement the current system. Additionally, there are research specific changes to the FMS that are not documented here but are covered in the ESWR, ACWO system. This document does not include information about the operation and use of the basic or research FMS, which is covered in existing operations manuals. The research FMS applications software is not covered in this document but is separately documented.

## 2.0 BASELINE RESEARCH FLIGHT MANAGEMENT SYSTEM

### 2.1 FMS GENERAL

The Research Flight Management System provides automatic navigation, guidance, flight planning, navigation map display, flight information, and flight performance optimization. The system makes use of information from several external aircraft systems coupled with algorithms programmed in the Honeywell FMC-PIP. The outputs from the Research FMS are fed to the main research computer where this information can be used in a variety of ways including feeding into the aircraft autopilot for automatic guidance. The Research FMS is not connected to the basic aircraft dual-FMS installation. However, all three are fed information from the same basic aircraft sensors and they share the same Honeywell FMC-PIP part numbers. This separation of basic aircraft and research systems insures that no interference can be induced into the basic aircraft systems from the experimental research system. This separation does provide for increased flexibility in the research system to provide new features and options for flight research.

FIGURE 1. RESEARCH FLIGHT MANAGEMENT SYSTEM



## 2.2 FMS MAJOR COMPONENTS

The major components of the Research FMS are shown in the block diagram of Figure 1. The major systems include the Honeywell Flight Management Computer - Product Improvement Package (FMC-PIP), the Flight Management System VME Computer, two FMS Control Display Units (CDU), the I/O Concentrator VME Computer, the Systran Inc. SCRAMNet+ fiber optic reflective memory bus, the Silicon Graphics Inc. Onyx Computer, and the Fieldworks ruggedized PC. The FMS VME Chassis and I/O Concentrator are stand-alone computers containing Motorola Power PC processors running the Wind River Systems VxWorks Real-time Operating System. The Fieldworks PC is a ruggedised Pentium PC running Microsoft Windows 98. The Silicon Graphics Onyx is an eight processor graphics computer running the SGI IRIX real-time Unix operating system. The Systran Inc. Shared Common Random Access Memory Network (SCRAMNet+) is a fiber optic based high-speed reflective memory system, which allows the simultaneous sharing of large blocks of global

## RESEARCH FLIGHT MANAGEMENT SYSTEM

memory variables among connected computer nodes. The two FMS Control Display Units are Lear Siegler Model 2577B units originally purchased for the retired B-737 research aircraft. The FMC-PIP, FMS VME Chassis, Fieldworks PC, and one FMS CDU are physically located on the Flight Management Pallet at Station 2 on the aircraft as shown in Figure 2. The second FMS CDU is located in the cockpit along with the two basic aircraft FMS CDU's. The Onyx and I/O Concentrator computers are located on their respective pallets at Stations 6 and 9. The SCRAMNet+ is distributed among several pallets in the aircraft.

### **2.3 FMS INTERFACES**

In a normal aircraft installation, the FMC will directly connect to several basic aircraft systems such as Air Data Computers, Inertial Reference Systems, Flight Control Computers and other systems as shown in Figure 4, via multiple ARINC 429 serial data bus interfaces. In the baseline Research FMS, the FMS-VME Computer provides all of the Research FMS sensor inputs. The Onyx and I/O Concentrator computers provide real or simulated sensor data to the FMC by passing the data to the FMS VME Computer over the SCRAMNet+ reflective memory system. The FMS VME Computer contains the necessary interface cards to provide two-way data transfer to and from the FMC-PIP. Consequently, FMC-PIP output data is passed to the Onyx/I/O Concentrator computers via the reverse path. This arrangement gives the Onyx and I/O Concentrator flight applications software complete control of the FMC-PIP input and output data including the routing of FMC guidance outputs to the autopilot.

## **3.0 FLIGHT MANAGEMENT COMPUTER**

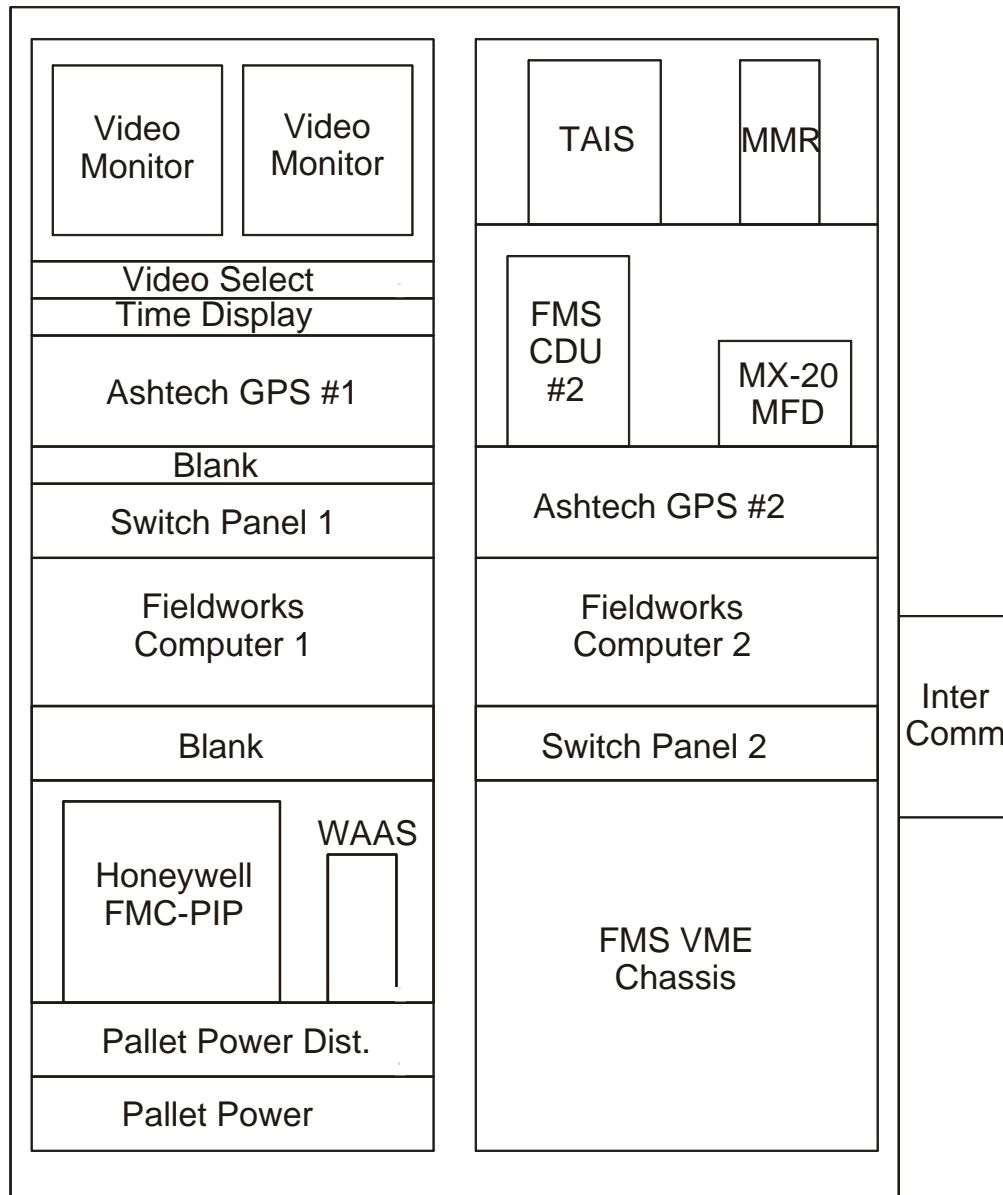
### **3.1 FMC GENERAL**

The Honeywell Flight Management Computer - Product Improvement Package (FMC-PIP) is the heart of the ARIES Research Flight Management System. The FMC-PIP, in conjunction with other aircraft systems, forms an integrated, full-flight regime control and information system, which provides automatic navigation, guidance, map display, and in-flight performance optimization. It is designed to reduce cockpit workload during each flight phase by eliminating routine tasks and computations normally performed by the flight crew. When coupled to the autopilot, flight director, and auto-throttle, the system can provide automatic guidance through integrated commands for controlling roll, pitch, and engine thrust. The FMC/FMS provides flight planning, navigation, database storage, navigation display, guidance, and performance optimization. The Honeywell FMC-PIP is compliant with the ARINC 702 specification and the part number is 4052506-941. The FMC-PIP is FAA certified for use on Boeing 757, 767, and 747-400 aircraft.

### **3.2 FMC CHASSIS**

The unit is housed in an 8-MCU chassis with dimensional, mounting, and cooling requirements of ARINC specification 600. The FMC-PIP is hard-mounted directly on the aircraft mounting rack and does not require shock or vibration isolation. The ARINC 600 size 2 connectors on the back of the unit are keyed to prevent incorrect mating. The FMC-PIP chassis is designed to hold a power supply and 13 circuit card assemblies (CCA). A mounting fan provides cooling air that enters the chassis through an opening in the bottom and is directed over the CCA's. The FMC-PIP requires 115 ( $\pm 11.5$ ) VAC, 400 ( $\pm 5$ ) Hz, single phase input power. The unit dimensions include a width of 10.25 inches, a depth of 15.02 inches, and a height of 7.64 inches. The FMC-PIP unit weighs 28.0 pounds and is physically located on the Flight Management Pallet at Station 2 as shown in Figure 2. The power and signal wiring is documented in the ESWR's, drawings, and wiring diagrams in Appendix B and D.

FIGURE 2. FLIGHT MANAGEMENT PALLET



FRONT VIEW

### 3.3 NAVIGATION

The navigation function of the FMC-PIP generates aircraft position, velocity, and altitude data for use in the FMC and other external aircraft systems. Navigation algorithms combine data from the Navigation Data Base, position and velocity data from the three IRS systems, range and bearing data from the DME and VOR receivers, and altitude and airspeed data from the Air Data Computers. The combined data is used to generate geodetic aircraft position, velocity, wind vector, altitude and flight path angle, local earth radius, and other data. The FMC-PIP has algorithms for the automatic navigation-aid selection based on aircraft position, desired track, and data from the Navigation Data Base and provides tuning outputs for the DME/VOR receivers. The Research FMC outputs are not connected to the basic aircraft DME/VOR receivers, therefore, this feature is not used. The Research FMC makes use of high accuracy GPS position data while the basic

## RESEARCH FLIGHT MANAGEMENT SYSTEM

aircraft FMC/FMS does not. The Onyx flight applications software receives GPS data from the Ashtech receivers, blends this data with IRS data and generates a hybrid position solution. This Onyx hybrid navigation solution is much more accurate than the normal IRS/DME/VOR solution generated in the basic aircraft FMC. The hybrid solution is formatted and fed into the FMC-PIP via ARINC 429 signals from the FMS-VME computer.

### **3.4 FLIGHT PLANNING**

The FMC-PIP allows for the input of complex 2-D and 3-D flight plans via either of the two CDU's. The pilot or operator can select from thousands of airports, runways, waypoints, nav aids, airways, approach and departure procedures defined in the Navigation Data Base to build a flight plan. Additionally, user defined waypoints can be entered based on latitude and longitude or distance and bearing from a pre-defined waypoint. Once entered, flight plans may be modified by adding, changing, or deleting any of its elements. The flight plans can be further modified with altitude and speed constraints, holding patterns, path offsets, etc. Two complete flight plans can be separately stored in the FMC and activated via CDU commands.

### **3.5 GUIDANCE**

The guidance function defines the two or three dimensional flight path to be flown and the necessary computations and outputs for aircraft control referenced to the defined flight path. The flight path may be defined in the lateral and/or vertical planes from flight plan and performance data entered into the FMC-PIP from the CDU and augmented with navigation and performance databases. The lateral flight plan is normally defined by a string of navigation waypoints. The lateral path between waypoints may be any of 16 navigation leg types required to fly all published ATC procedures. The vertical and thrust guidance functions are closely integrated with performance management functions for optimum three-dimensional path guidance. The FMC-PIP computed guidance output parameters include desired track, track angle error, bearing and distance to the active waypoint, lateral and vertical path deviation, and speed error. These guidance outputs can be fed into the aircraft autopilot via the Onyx Computer, I/O Concentrator, and Pilot Select Panel (PSP).

### **3.6 MAP DISPLAY**

The FMC-PIP generates both dynamic map and map background data outputs which normally go to the EFIS on an ARINC 429 high-speed link. Dynamic map data is normally related to the airplane motion with respect to the flight plan and includes such data as airplane track, ground speed, time and distance to go, computed winds and vertical/lateral deviations from the active flight path. The computed background map data includes the location of waypoints, nav aids, obstacles, and airports within the EFIS field of view. In the map mode, dynamic map data must be updated to reflect aircraft motion and is computed at 10 Hz. The background data is normally slow changing and is updated every three seconds. The Research FMS EFIS output data is used by the Onyx computer to generate a map display on the research displays in the cockpit and the Onyx Operators Station. There is no connection between the Research FMS and the basic aircraft EFIS.

### **3.7 DATABASE**

The Navigation Data Base contains all of the nav aid, airport, airway, approach, and departure information required to operate the aircraft in the national airspace system. The FMC-PIP has 1 MB of non-volatile bubble memory reserved for this purpose. The ARINC 424 compatible database is updated on a 28-day cycle and the memory is large enough to hold two update cycles. The Research FMS Navigation Data Base is customized for NASA by Honeywell and updated as needed to satisfy research goals rather than on a fixed cycle while the basic aircraft FMS database is maintained on the normal update cycle. The non-volatile memory also holds the FMC operations program, performance data for the aircraft model and engine configuration, and specific customer option data. Data is loaded into the FMC-PIP from floppy disks using a standard ARINC 615 compatible data loader, which can be connected via a loader connector on the rear of the FMS Pallet.

**FIGURE 3. RESEARCH FLIGHT MANAGEMENT  
SYSTEM VME COMPUTER CHASSIS**

Slot 1 MVME-1604 POWER PC CPU
Slot 2 POWER PC CPU Expansion
Slot 3 - Empty
Slot 4 SYSTRAN SCRAMNet+ Card
Slot 5 VMI-2128 Discrete Output Card
Slot 6 VMI-1129 Discrete Input Card
Slot 7 MVME-162-010A Condor ARINC 429 Card #1
Slot 8 - A-429 Cable Expansion
Slot 9 - Empty
Slot 10 MVME-162-010A Condor ARINC 429 Card #2
Slot 11 - A-429 Cable Expansion
Slot 12 Empty
Slot 13 VMIVME-6016 16-Channel Serial Controller
Slot 14 Empty
Slot 15 - Audio Alert PROTO XVME085
Slot 16 - 19 Empty
Slot 20 MVME-760-001 Power PC Transition Card

### **3.8 PERFORMANCE**

The performance function manages aircraft flight profile by computing display data that assists the pilot in making decisions and commands that cause the aircraft to be controlled according to the selected flight plan. Algorithms in the FMC-PIP compute speed, thrust setting, and vertical guidance commands to meet the selected mode objectives, but are subject to aircraft performance limits and flight plan constraints. Prediction data is computed such as distance, time of arrival, altitude, speed, and fuel at future points on the active flight plan. Other performance calculations include warning messages if future flight plan constraints cannot be met, optimum and maximum cruise altitudes, time and fuel limits, climb and descent limits, and engine out drift down.

## 4.0 FMS-VME COMPUTER

### 4.1 CHASSIS

The Flight Management System VME Computer is a complete stand-alone computer system. The VME chassis itself is a ruggedized off-the-shelf enclosure, which was physically and electrically modified to fly on the B-757 aircraft. Additional shock and vibration testing was performed on the chassis in NASA Langley laboratories to qualify the chassis for flight. The unit features all metal heavy gauge aluminum construction. The enclosure has 20 slots for standard 6U x 160 mm VME cards, a 500 Watt power supply and runs on 115 VAC @ 60 Hz aircraft power. The unit card configuration is shown in Figure 3. The VME chassis has several spare card slots available for future expansion. The chassis is configured with transition cables that run from each interface card to flight qualified connectors mounted on the back of the chassis. The card, cable and connector configuration is further documented in the set of aircraft drawings and wiring diagrams at the end of this document.

### 4.2 CENTRAL PROCESSOR

The CPU card is an MVME-1604 Motorola Power PC single board computer which takes up the first two slots in the chassis. The CPU chip is the 32 bit Motorola MPC604 processor running at 133 MHz. The board is configured with 32 MB of DRAM memory, 0.5 MB of boot ROM, two RS-232 serial ports, one parallel port, SCSI interface, real-time clock, four timers, and a 10base-T Ethernet interface. The card also has a VGA compatible video port, keyboard port, mouse port, and other memory expansion capabilities. The CPU card has programmable ROM chips and self-booting capability but is currently configured to boot over the aircraft local network from the Onyx computer that also is a network file server. The Unix real-time operating system used for CPU card is VxWorks V5.3 from Wind River Systems, Inc. The application software is loaded into flash RAM from the network boot process for execution. The software tasks associated with the operation and control of the processor module include: managing the VME bus and all VME module registers; handling bus interrupts; providing status of all real-time tasks; interfacing to the monitor/console (Fieldworks computer) via serial port COM1; initializing and verifying all cards can be addressed and reporting errors or non functioning cards.

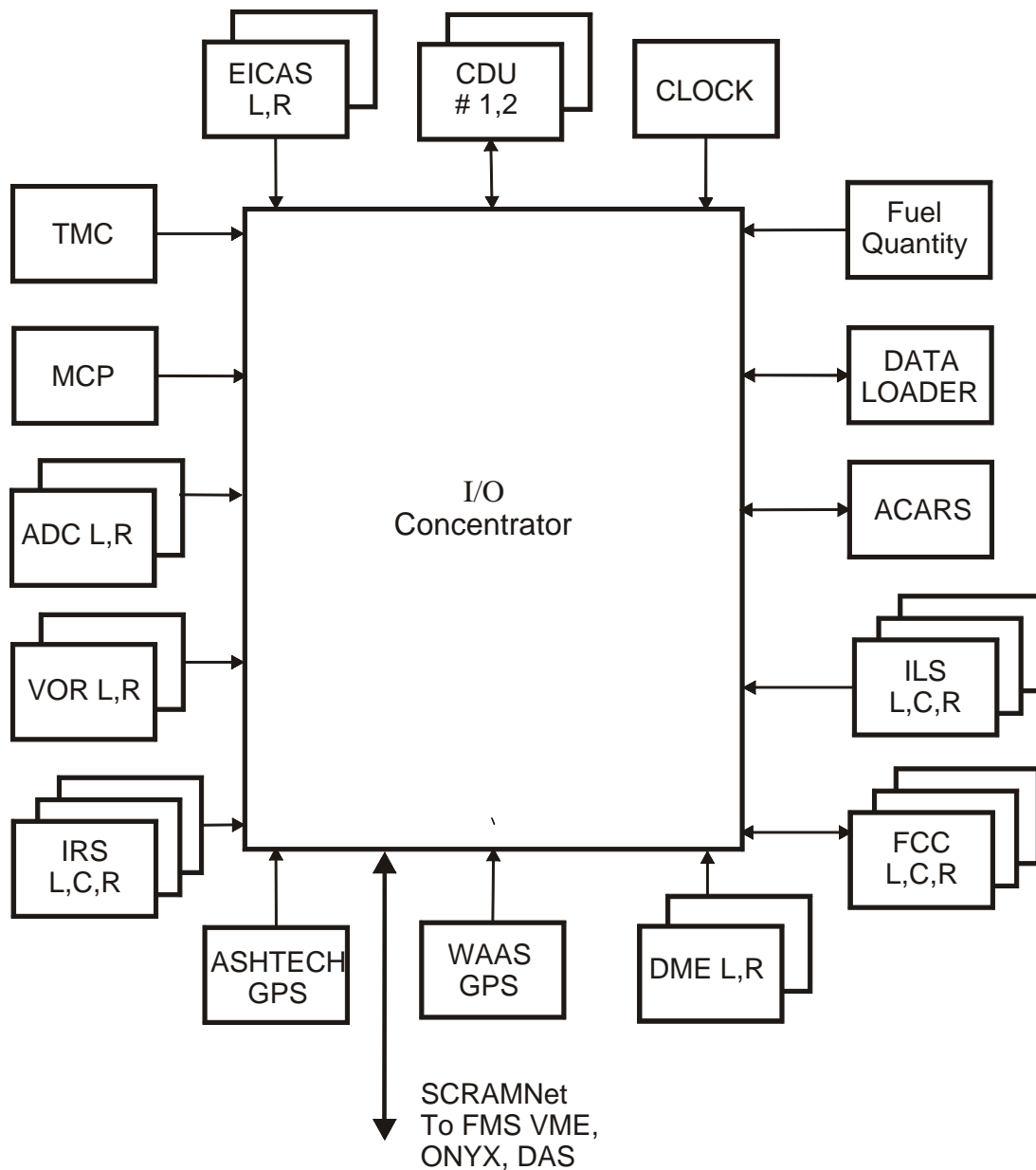
### 4.3 VME BUS ANALYZER

Slot three is vacant but reserved for a VME bus analyzer card for trouble isolation and software development. The VMETRO VBT-325 along with its piggyback modules is a comprehensive VME Bus analysis system, which can automatically screen the VMEbus for violations of the bus protocol, like illegal signal sequences or timing, and glitches on address and data lines. Additionally, the unit features a 200MHz timing analyzer for the VMEbus. The unit is operated from a menu-driven user interface, which is accessed via a terminal emulator running on the Fieldworks Laptop computer. The bus analyzer card can be inserted in the chassis as needed for trouble isolation, software development, or VME bus monitoring functions, and removed when not needed.

### 4.4 SCRAMNET INTERFACE

The Systran, Inc., SCRAMNet+ VME6U board takes up one slot in the chassis. The SCRAMNet+ card handles all of the FMC related I/O between the FMS-VME and Onyx computer. All of the VME input and output data with the exception of the console monitor port, and Ethernet port is transferred via the SCRAMNet+ card. This module provides 2MB of networked memory for shared data within the VME address space. Figure 4 shows the FMS related basic aircraft systems that input data for distribution over the SCRAMNet+ to the FMS-VME Computer. The VME software tasks associated with the operation and control of the SCRAMNet+ module include: initialization of all SCRAMNet module control registers; initialization and allocation of all shared memory; setup and handling of interrupts. Additional SCRAMNet+ bus details are discussed in section 7.

FIGURE 4. RESEARCH FLIGHT MANAGEMENT SYSTEM INTERFACE



#### 4.5 DISCRETE INPUT

There are 128 discrete input channels available through the use of one VMIVME-1129 card. The VMIVME-1129 Digital Input Board is designed to read a voltage from a variety of devices. The signals may originate from electronic switching circuits, standard logic circuits, mechanical switch contacts, relay contacts, or numerous other sources. The inputs can be configured for current sinking or voltage sourcing input signals. Each group of eight input signals are jumper selectable to monitor voltage source or current sinking signals. Other features of the VMIVME-1129 Digital Input Board include: built-in-test logic for fault detection and isolation; selectable input voltage thresholds from 1.25 to 34 volts DC; 8, 16, or 32 bit data transfers, front panel fail LED; and 3 msec input noise suppression filter. Currently, 60 of the 128 input discrete channels are wired to the VME chassis outside world connector of which, only 13 are currently used.

## RESEARCH FLIGHT MANAGEMENT SYSTEM

### **4.6 DISCRETE OUTPUT**

One VMIVME-2128 card is used to provide up to 128 output discrete channels. The board is designed for a variety of applications such as relay drivers, lamp drivers, solenoid drivers, stepper motor drivers, LED drivers, and fiber-optic drivers. The board is capable of delivering high voltage and/or high current sink outputs. The open collector output drivers will support output voltages from 5 to 48 VDC. The VMIVME-2128 board has a built-in-test feature, which allows the user, under software control, to verify the operation of each output channel. Other features of the VMIVME-2128 include: 8, 16, or 32 bit data transfers, front panel fail LED; fault protection for outputs; high current open collector drivers (600 mA sink) with built-in suppressor diodes; outputs may be paralleled for high drive capability; optional open collector pull-up resistors; and user configurable address jumpers. Currently, 60 of the 128 output discrete channels are wired to the VME chassis outside world connector of which, only 34 are used.

### **4.7 ARINC 429 INTERFACE**

Two Condor Engineering MVME-162-010A boards handle ARINC 429 serial I/O. The Condor ARINC 429 module is an intelligent I/O device with its own on-board processor and memory buffer. Each Condor board can accommodate 16 receive channels and 8 non-multiplexed transmit channels. The transmit and receive channels can be programmed as high speed (100 KBs) or low speed (12.5 KBs) in channel pairs. The vast majority of the data that flows in and out of the FMC goes through the ARINC 429 channels.

### **4.8 SERIAL COMMUNICATIONS**

Since the original baseline configuration, one VMIVME-6016 VMEbus Intelligent 16-Channel Asynchronous Serial Controller interface card was added to accommodate experimental I/O requirements. Each of the RS-232 channels is individually programmable for data rates up to 38,400 baud and for XON/XOFF or hardware flow control. The board features an onboard processor, programmable buffers, DMA access, 6-pin RJ-12 connectors, LED fail indicator, and programmable interrupts. The six I/O signals are standard RS-232 signals including Transmit Data (TXD), Receive Data (RXD), Request to Send (RTS), Clear to Send (CTS), Data Carrier Detect (DCD), and Ground (GND).

### **4.9 AUDIO OUTPUT**

Another addition since the original baseline is a programmable Audio Alert card. This card allows the triggering of programmed voice messages in response to logical events determined in the Onyx applications software. As research dictates, different messages may be recorded and loaded into non-volatile memory using an external PC. The voice messages are fed into the aircraft inter-phone system for distribution throughout the airplane.

### **4.10 CPU TRANSITION**

An MVME-760-001 Power PC Transition card takes the last VME card slot. This card works in conjunction with and is connected to the CPU card. It provides the interface between standard Ethernet, parallel port, and the two serial port connectors and the host board connector. The Ethernet and parallel ports contain passive circuitry only. The I/O controllers reside in the host CPU board. The serial ports contain active circuitry to provide multiplexing and buffering functions.

## **5.0 CONTROL DISPLAY UNIT**

### **5.1 CDU GENERAL**

There are two Lear Seigler Incorporated Model 2577B Control Display Units (CDU) in the ARIES B-757 Research Flight Management System. Information is displayed by means of 14 lines of 24 alphanumeric characters on a five-inch, raster scan, monochrome cathode ray tube (CRT). Data entry and mode control is accomplished through a 69 push-button keyboard containing a full set of alphanumeric keys as well as

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Function, Mode, and Line Select Keys. The CDU has two high-speed (100 KBs) ARINC 429 input busses and one low speed (12.5 KBs) output channel. Only one input and one output bus is currently used.

### 5.2 **CDU LEGACY**

Eight of these CDU's were originally purchased for the research system in the NASA Langley B-737 research aircraft that is now retired and the corresponding simulator facilities. Money was saved by using the Lear Siegler CDU's as opposed to purchasing a number of FMC-PIP compatible units from Honeywell. The number one CDU is mounted in the cockpit on the center isle stand. This unit is the third CDU in the cockpit with two CDU's belonging to the basic aircraft FMS. The cockpit CDU allows pilot or center seat observer access to the Research Flight Management System. The number two CDU is located at the Flight Management Pallet and both CDU's allow full access to all FMS functions and operate in parallel with the Research FMC-PIP. If the cockpit crew is busy, all programming can be performed at the FMS Pallet and vice versa.

### 5.3 **CDU INTERFACE**

Normally, the CDU's communicate directly to the FMC-PIP via ARINC 429 interface connections. However, the Lear Siegler CDU's use the 429 interface but a different proprietary communications protocol than the Honeywell units that comply with the ARINC 739 protocol standards. The Onyx flight applications software performs a translation between the Lear Siegler CDU's and Honeywell FMC to allow them to work together. The I/O Concentrator provides all of the required ARINC 429 interface connections to the two CDU's. The I/O Concentrator communicates with the translation software in the Onyx Computer software via the SCRAMNet+. The CDU's are interfaced to the I/O Concentrator rather than the FMS-VME Computer to match the configuration of the ground based simulation facilities and for software compatibility.

## 6.0 **FIELDWORKS PC**

### 6.1 **FIELDWORKS GENERAL**

The Research Flight Management System has two Fieldworks model FW7000 general purpose 233 MHz Intel Pentium based IBM compatible personal computers running the Microsoft Windows 98 operating system. The Fieldworks PC is designed to work in harsh environments and meets several military specifications for shock and vibration. Each computer has three ISA bus and three PCI bus expansion slots, CD-ROM, floppy disk, SVGA graphics, PC card slots, two serial ports, and one parallel port. The computers will accept 10.5-30 VDC or 100-250 VAC at 47-400 Hz input power.

### 6.2 **FIELDWORKS CONFIGURATION**

The two Fieldworks PC's are configured with additional interface cards to allow them to serve a variety of functions. Each Fieldworks computer is configured with a network interface card (NIC), a time and frequency processor (TFP) card, an ARINC 429 interface card, and an RS-422 serial interface card. The serial ports allow the computers to be used as terminals for the FMS-VME computer and Ashtech GPS receivers. The network cards allow the Fieldworks computers to connect to the local area network (LAN) on the aircraft or to the Langley Research Center wide area network (WAN) when the aircraft is in the hangar. The LAN connections allow the Fieldworks computers to access and monitor flight information from the Onyx main computer in real-time. The LAN also allows data and files to be passed between all computers on the network. The TFP cards allow the Fieldworks computers to synchronize their internal clocks to UTC via the IRIG-B timing signals distributed throughout the aircraft. This provides for the logging of data with UTC time stamping. The ARINC 429 interface cards provide the capability to monitor selected aircraft systems such as GPS receivers, Inertial Reference Systems (IRS), Air Data Computers (ADC), or FMC input or output busses. The RS-422 serial cards are used to interface the Fieldworks computers to the Wide Area Augmentation System (WAAS) GPS receiver, which has both ARINC 429 and RS-422 I/O. Changing research needs require frequent modifications to the Fieldworks computer I/O.

## 7.0 SCRAMNET

The SCRAMNet+ is a communications network geared to real-time applications, and based on a replicated, shared-memory concept. Each host processor on each node has a local copy of shared memory that is updated over a high-speed, serial-ring network. Originally developed for real-time, high fidelity simulators, the system has been adapted for flight research. The network is designed to provide high-speed, low-latency transfers of data between many different types of computers all working to solve different portions of the same real-time problem. Each host processor on each node has a local copy of 2 MB of shared memory, which is updated over a high-speed, serial-ring network. There are four major nodes on the baseline SCRAMNet+ network including the FMS-VME Chassis, Onyx Computer, I/O Concentrator, and Data Acquisition System (DAS). Additional nodes can be added as required by changing research needs. Each processor on a node maps its global data structures into the shared dual-port memory on each SCRAMNet+ node. When an application process updates a data structure, the address and data are automatically broadcast to all nodes on the network. This allows all computers on the SCRAMNet+ network to operate simultaneously on the same set of data. Figure 4 shows many of the basic aircraft systems that input data for distribution over the SCRAMNet+. The network features include: a ring topology with 150 Mbits/s line transmission rate; 256 node capacity on each ring; Burst Mode protocol with fixed-length message packets of 82 bits; Burst Plus Mode with variable-length packets of 256 or 1024 bytes; Platinum Mode with error corrected packets of 82 bits; and a data filter that allows only changed data to be communicated to other nodes.

## 8.0 I/O CONCENTRATOR

### 8.1 I/O CONCENTRATOR GENERAL

The Input/Output (I/O) Concentrator VME Computer is a complete stand-alone computer system very much like the FMS-VME Computer. The identical processor, VME chassis, and many of the same interface cards are used in each system. However, the I/O Concentrator is basically full of interface cards while the FMS-VME has spare card slots. The I/O Concentrator's basic function is to gather all of the required aircraft analog, discrete, and ARINC 429 sensor data from the basic aircraft systems and provide this data to the flight applications software running in the Onyx Computer via the SCRAMNet+ interface. The FMS related basic aircraft system I/O Concentrator inputs are shown in Figure 4. The I/O Concentrator works in conjunction with an ARINC 429 isolation box, which provides another level of protection between the basic aircraft sensors and the research systems. The basic aircraft ARINC 429 outputs are fed to the isolation box and its outputs are fed to the I/O Concentrator. The I/O Concentrator also serves as an interface between both FMS-CDU's and the Onyx computer via the ARINC 429 and SCRAMNet+ interfaces.

### 8.2 TIME SYNCHRONIZATION

The I/O Concentrator also provides time synchronization for the entire aircraft with the use of a time and frequency processor (TFP) card. The Ashtech GPS receiver #1 on the Flight Management Pallet provides the required analog 1 Pulse Per Second and RS-232 serial NMEA signal inputs required to synchronize the TFP to the atomic clocks in the GPS constellation. The TFP outputs are routed to the Onyx computer and the Data Acquisition System (DAS). The DAS distributes UTC to each pallet via an IRIG-B timing signal distribution system for display of UTC in the cockpit and each pallet.

## 9.0 ONYX COMPUTER

The Onyx research computer is manufactured by Silicon Graphics Inc. (SGI) and was flight hardened for aircraft installation by CRI of Austin Texas. The Onyx is the primary research computer on ARIES and is host to the primary flight applications software. The Onyx is optimized for graphics processing and has three graphic pipes, which can drive up to 18 displays at 1024 x 768 pixel resolution at 60 Hz. The machine has eight 200 MHz CPU's and runs the SGI IRIX operating system which is a real-time version of Unix. The primary I/O is via the SCRAMNet+ fiber optic network, but the computer also has Ethernet and RS-232 ports for console/terminal communications. The Onyx requires 7 KVA of input power and 40° F cooling air flowing

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at 850 cfm. The Onyx is cooled by the ships cooling packs and is connected directly by a custom-built mix manifold to the underside of the Onyx rack. On top of the Onyx, two plenums duct the exhaust air down the side of the rack and into the cargo bay. The Onyx Operator Station has been designed and built to allow operations personnel to control and monitor the operation of the Onyx computer. The Onyx Operator Station has a duplicate set of research displays to monitor the Onyx generated EADI and MAP displays. The Onyx computer is located at Station 6. The Onyx Operator Station is located directly behind the Onyx computer and is designated Station 8. The computer also serves applications program files for the FMS-VME and I/O Concentrator Computers allowing these systems to boot over the LAN. The Onyx operator station has a three-person seat installed for operations personnel.

## APPENDIX A: REFERENCE PUBLICATIONS

Boeing 757/767 Product Improvement Package (PIP) Flight Management System Guide, Honeywell Inc., June 1994.

Flight Management Computer System (FMCS) Interface Control Document (ICD), Boeing Document No. D242T105, Rev H, 6/28/95.

FMC User's Guide B-757/767/747 Non PIP - PIP, Bill Bulfer and Skeet Gifford, 1996.

Honeywell Component Maintenance Manual - ATLAS, PN 4052506,

ARINC Specification 424 Navigation System Data Base, Aeronautical Radio, Inc., December 31, 1995.

ARINC Characteristic 429P1-15 Mark 33 Digital Information Transfer System (DITS) Part 1 Functional Description, Electrical Interface, Label Assignments and Word Formats, Aeronautical Radio, Inc., September 1, 1995.

ARINC Specification 600-12 Air Transport AVIONICS Equipment Interfaces, Aeronautical Radio, Inc., November 10, 1998.

ARINC Report 615-3 Airborne Computer High Speed Data Loader, Aeronautical Radio, Inc., August 15, 1992

ARINC Specification 702A Advanced Flight Management Computer System, Aeronautical Radio, Inc., January 31, 2000.

ARINC Characteristic 739-1 Multi-Purpose Control Display Unit, Aeronautical Radio, Inc., June 20, 1990.

MVME1603/MVME1604 Single Board Computer Programmer's Reference Guide, Motorola Inc., February 1995.

MVME760 Transition Module User's Manual, Motorola Inc., January 1995.

VMIVME-2128 128-bit High Voltage Digital Output Board Instruction Manual, VME Microsystems International Corporation, Document No. 500-002128-000 G, Revised March 20, 1997.

SCRAMNet+ Network VME6U Hardware Reference, Systran Corporation, Copyright 1995-1996, Revised July 5, 1996.

NASA Transport Research Facilities Requirements Document, Version 3.3, July 1996.

VMIVME-2129 128-bit Digital Input Board With Built-In-Test Instruction Manual, VME Microsystems International Corporation, Document No. 500-002129-000 D, Revised June 2, 1994.

VME-429 User's Manual, Condor Engineering Inc., Copyright 1994-1996, Rev 1.11, April 12, 1996.

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### APPENDIX B: EXPERIMENTAL SYSTEM WORK REQUESTS

The ESWR is the primary document describing the technical details of the installation and/or modification of experimental systems on ARIES. These documents contain drawings, diagrams, and other required technical information concerning the research system. Subsequent ESWR's detail additional research specific modifications made after the original baseline configuration. These are official documents and are maintained by the Systems Development Branch (SDB) of the Airborne Systems Competency.

ESWR #	DESCRIPTION
NFM-001	Flight Management System
NFM-002	Ashtech GPS System
NFM-003	Fieldworks Computers
NFM-004	WAAS GPS Receiver
NFM-005	Ashtech GPS
NFM-013	FMS VME RS-232 Serial I/O

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## APPENDIX C: ABBREVIATIONS AND ACRONYMS

ADC	Air Data Computer
AFD	Aft Flight Deck (proposed research cab in 757)
ACARS	ARINC Communication And Address Reporting
ADC	Air Data Computer
AirSC	Airborne Systems Competency
ARIES	Airborne Research Integrated Experiment System
ARINC	Aeronautical Radio, Inc (ARINC)
ATC	Air Traffic Control
CCA	Circuit Card Assembly
CDU	Control Display Unit
CFM	Cubic Feet per Minute
CPU	Central Processing Unit
DAS	Data Acquisition System
DGPS	Differential Global Positioning System
DME	Distance Measuring Equipment
EADI	Electronic Attitude Director Indicator
EICAS	Engine Indication Crew Alerting System
EHSI	Electronic Horizontal Situation Indicator
ESWR	Experimental Systems Work Request
FAA	Federal Aviation Administration
FCC	Flight Control Computer
FMC	Flight Management Computer
FMS	Flight Management System
FQP	Fuel Quantity Processor
GPS	Global Positioning System
Hz	Hertz, Cycles Per Second
ILS	Instrument Landing System
INS	Inertial Navigation System
I/O	Input Output
IRIG	Inter Range Group
IRS	Inertial Reference System
ISA	Industry Standard Interface
KBS	Kilo Bits Per Second
KVA	Kilo Volt Amperes
LAN	Local Area Network
LED	Light Emitting Diode
LNAV	Lateral Navigation
MB	Mega-Byte
MCP	Mode Control Panel
MCU	Modular Component Unit
MFD	Multi-Function Display
MMR	Multi-Mode Receiver
NAVAID	Navigation Aid (DME, VOR, ILS)
NIC	Network Interface Card
PC	Personal Computer
PCI	Personal Computer Interface
PIP	Product Improvement Package
PSP	Pilot Select Panel
RFD	Research Flight Deck
SCRAMNet	Shared Common Random Access Memory Network
SDB	Systems Development Branch
SID	Standard Instrument Departure
STAR	Standard Arrival Route
TAIS	Total Aircraft Information System
TFP	Time and Frequency Processor
TMC	Thrust Management Computer
TRF	Transport Research Facilities
UTC	Universal Time Coordinated

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VME	Versabus Microcomputer Eurocard
VNAV	Vertical Navigation
VOR	Visual Omni Range
WAAS	Wide Area Augmentation System
WAN	Wide Area Network

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### APPENDIX D: RESEARCH FMS DRAWINGS

The 25 Research Flight Management System drawings listed below are official controlled documents maintained and updated by the Systems Development Branch (SDB) of the Airborne Systems Competency (AirSC). All drawings were generated with the FutureNet V6.10 Schematic Designer computer aided design program from the Data I/O Corp. The drawings are maintained by SDB in electronic form as well as "B" size (11"x17") signed paper copies. These drawings should be checked for the latest revision levels, which may change due to flight research required modifications.

DRAWING #	DESCRIPTION
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1157655	RS-232 ABCD Switch (1 of 1)
1157917	Station #2 Baseline FMS Power Distribution Panel B-202 (2 of 3)
1157926	Ashtech GPS Z-12 Receiver / Radio Modem (1 of 1)
1157928	Flight Management Pallet Layout (1 of 1)
1157929	FMS Pallet Power Distribution (1 of 1)
1157930	FMS VME I/F Panel B-212 (1 of 1)
1157931	FMS VME Chassis Wiring Discrete Input / Output (1 of 1)
1157932	FMS VME Chassis Wiring ARINC 429 (1 of 1)
1157933	Honeywell FMC PIP I/O Wiring (4 of 4)
1157935	FMS CDU Interface (1 of 1)
1157936	FMS Interface Panel B-291 (1 of 1)
1157938	FMS VME Chassis Interface Wiring (1 of 1)
1157954	FMS Pallet GPS Interface Panel B-292 (1 of 1)
1157962	Ashtech GPS System (2 of 2)
1157963	WAAS GPS Receiver System (1 of 1)
1157964	Fieldworks Computer System (2 of 2)
1168898	B-293 GPS - TX Switch (1 of 1)
1168936	FMS VME Chassis Wiring RS-232 Serial I/O (1 of 1)
1168959	FMS VME Audio Alert (1 of 1)